Physical frailty in older men: prospective associations with diet quality and patterns

Abstract

Background

Increasing numbers of older adults are living with frailty and its adverse consequences. We investigated relationships between diet quality or patterns and incident physical frailty in older British men and whether any associations were influenced by inflammation.

Methods

Prospective study of 945 men from the British Regional Heart Study aged 70-92y with no prevalent frailty. Incident frailty was assessed by questionnaire after 3 years of follow-up. Frailty was defined as having at least three of: low grip strength, low physical activity, slow walking speed, unintentional weight loss and feeling of low energy**, all based on self-report**. The Healthy Diet Indicator (HDI) based on WHO dietary guidelines and the Elderly Dietary Index (EDI) based on a Mediterranean-style dietary intake were computed from questionnaire data and three dietary patterns were identified using principal components analysis: prudent, high fat/low fibre and high sugar.

Results

Men in the highest EDI category and those who followed a prudent diet were less likely to become frail [top vs bottom category odds ratio (OR)(95% CI) 0.49 (0.30, 0.82) and 0.53 (0.30,0.92) respectively] after adjustment for potential confounders including BMI and prevalent cardiovascular disease. No significant association was seen for the HDI. By contrast those who had a high fat low fibre diet pattern were more likely to become frail [OR (95%CI) 2.54 (1.46,4.40)]. These associations were not mediated by C-reactive protein (marker of inflammation).

Conclusions The findings suggest adherence to a Mediterranean–style diet is associated with reduced risk of developing frailty in older people.

Key words: Frailty, diet, older people

Key points:

- Healthier dietary intake was associated with lower risk of frailty three years later

- This was not explained by inflammation (C-reactive protein) and suggests other mechanisms operating

- Encouraging older adults to adhere to the guidelines based on a Mediterranean–style diet may prevent or delay frailty onset.

Introduction

Frailty is a distinctive health state related to the ageing process and represents a vulnerability to adverse health outcomes after an apparently minor event which provides a health challenge [1]. One of the most common approaches to conceptualising frailty is by using the Fried frailty phenotype model which defines frailty as the presence of at least three of five physical characteristics; slow walking speed, low grip strength, low physical activity (PA) levels, exhaustion and unintentional weight loss [2]. In the UK 7% in community dwelling men aged 65 years are reported to be frail [3]. Frailty prevalence increases with age [4] and is associated with increased mortality, [4] hospitalisation [5] and disability [6]. Older adults transition frequently between frailty states over time [7] and physical frailty has the potential to be treated or prevented, improving quality of life and reducing healthcare costs [8]. Whilst insufficient food intake may be related to frailty in a proportion of cases, the picture is complicated by the fact that frailty also occurs with obesity [9], and diets in overweight or obese older people may be energy dense but low in micronutrients [10]. However, diet composition beyond intake of calories is suspected to influence frailty [11]. Interest in diet and chronic disease has shifted in recent years from specific nutrients to overall diet quality and patterns measured using either *a priori* approaches, which use predefined dietary scores based on dietary guidelines, or *a posteriori* approaches, in which patterns are derived from the data, for example using principal component or cluster analysis. Few cohort studies have explored relationships with frailty and findings are varied; some suggest that better diet quality or healthier patterns reduce the risk of frailty [12,13] whilst others are inconclusive [14]. The age-related increases in chronic low grade inflammation have also been hypothesised to play a role in frailty; inflammatory markers such as C-reactive protein (CRP) and interleukin-6) have shown to be higher in people who are frail[15]. None of the cohort studies on diet quality and frailty we identified, or any of the trials reviewed by Puts *et al* [8],

was based in the UK. The cohort studies investigated populations in Spain, Italy, Germany, Hong Kong and the US, countries likely to have markedly differing dietary patterns. Despite limited information on food and nutrient intake in older adults in the UK there are concerns about levels of some micro- and macro-nutrients in the diet [16,17]. We have previously shown in a study of British men that healthier eating patterns at age 58–79 years was associated with lower odds of mobility limitation 15 years later which specifically assesses locomotor disability or lower extremity disability [18]. Although frailty and disability are closely related and often co-exist they are considered distinct clinical entities [19]. Disability reflects dependency while frailty reflects a state of vulnerability to adverse outcomes in older people. Frailty can exist without the presence of multimorbidity and disability [1,19] and is a progressive condition that begins with a preclinical stage thus offering opportunities for early prevention [1]. The aim of this study was to therefore investigate whether healthier eating patterns in this older cohort of men when aged 70-92 years, indicated by pre-existing diet quality scores, or *a posteriori* dietary patterns were associated with a lower risk of frailty, and whether any associations were influenced by inflammation, as indicated by CRP level.

Methods

Sample

The British Regional Heart Study follows 7,735 men recruited from primary care practices in 24 British towns in 1978-80. This analysis uses baseline data from 2010-2012 when 3,137 survivors were asked to complete a general lifestyle questionnaire and a food frequency questionnaire (FFQ) and were invited to a physical examination and follow up data from 2014 collected by questionnaire. Men reporting heart failure at baseline were excluded. The National Research Ethics Service (NRES) Committee London provided ethical approval.

Participants provided informed written consent to the investigation in accordance with the Declaration of Helsinki.

Dietary assessment/patterns

We examined diet quality using (i) two *a priori* pre-defined diet quality scores (the Healthy Diet Indicator (HDI) and the Elderly Dietary Index (EDI)) based on recommended diets or dietary guidelines and (ii) an *a posteriori* exploratory approach to derive dietary patterns. Dietary intake was measured using a self-administered FFQ used as described previously in this cohort and we derived the HDI and EDI scores with slight modifications [20]. The FFQ has been validated in the British population against weighed food intake [21]. Briefly, the HDI consists of 9 components made up of food groups and nutrients based on WHO nutrient intake guidelines (saturated fatty acids, polyunsaturated fatty acids, protein, carbohydrates, sugar, fibre, cholesterol, pulses/nuts/seeds, and fruit/vegetables), each scoring 1 if the dietary guideline was met and zero otherwise. We omitted pulses/nuts/seeds from the HDI because we did not have data for this component, resulting in a total score range from 0 to 8. The EDI as a marker of a Mediterranean-style diet [22], consists of 9 food components (meat, fish and seafood, legumes, fruit, vegetables, cereals, bread, olive oil, and dairy), each assigned 1-4-points with 4 points being assigned to the most healthy consumption frequency (not necessarily the highest frequency). The total score range for the EDI was 9 to 36. Higher scores on both the HDI and EDI indicated a healthier diet. We aggregated the 86 items from the FFQ into 34 food groups [23] on which we conducted principal component analysis using orthogonal varimax rotation to identify dietary patterns. Food groups with a factor loading of >0·20 or < −0·20 were considered to be important contributors to the dietary pattern and the participant's score was calculated by summing the food group intakes, each weighted by their factor loading. Three principal components were retained, with higher scores indicating

higher adherence to the pattern [23]. Total energy intake was estimated using a computer program based on the UK food composition tables [24] which assumed standard portion sizes.

Frailty

At baseline frailty was based on the 5 components of the Fried phenotype; (1) unintentional weight loss defined as ≥5% decrease in self- reported weight from 2007 with the loss being reported as unintentional; (2) weakness defined as being in the lowest quintile for grip strength; (3) low physical activity defined as being inactive based on a score derived from questionnaire data [25]; (4) exhaustion defined as reporting not feeling full of energy; and (5) slow walking speed defined as being in the lowest quintile of measured walking speed. Men meeting the frailty criteria on at least three components were defined as frail. At follow-up frailty status was based on subjective measures of frailty components collected by questionnaire, found to be as predictive of disability, falls and death as objective measures in our study [26]. Low grip strength was defined as a self-rating of fair or poor compared to other people the same age, slow walking speed a self-rating of slow walking pace and weight loss based on self-reported weight loss in the last 4 years [27].

Covariates

Social class was based on longest held occupation at study entry (1978–80) and categorised using the Registrar General's Social Class Classification (I, II III non-manual, III manual, IV and V). We collapsed these into two categories, manual and non-manual. Prevalent cardiovascular disease (diagnosis of heart attack, heart failure, or stroke (with symptoms lasting >24 h), smoking and alcohol consumption were reported by self-complete questionnaire. Region of residence (1978–80) was grouped into Scotland, North, Midlands

and South of England. Body mass index (BMI, kg/m2) was calculated from measured height (Harpenden stadiometer) and weight in light indoor clothing (Tanita BC-418 or Tanita scales if the participant had a pacemaker or defibrillator). Fasting venous blood samples were analysed for CRP (mg/L) using ultrasensitive assay on an automated clinically validated analyser (e411; Roche, Burgess Hill, UK) using the manufacturer's calibrators and controls (coefficient of variation 6.9%).

Statistical analyses

Demographic and anthropometric characteristics were calculated by frailty at baseline, and we used logistic regression models to investigate associations between dietary quality or pattern at baseline and frailty at follow-up after excluding men who were frail at baseline. The HDI and EDI scores were analysed as 4 groups of as equal size as possible; for the EDI score 9-22, 23-24, 25-26, 27-36 and for the HDI score 0-1, 2, 3, 4-8. The dietary patterns were classified as quartiles. P values for a trend were calculated by entering dietary categories or quartiles into the regression model as a continuous variable. All models were adjusted for age, social class, region of residence, cardiovascular disease, smoking, alcohol consumption, and energy intake.

Results

At baseline of 3137 men invited, 1722 attended the physical examination, of whom 36 were excluded due to heart failure. 1660 men provided data for frailty, 17% of whom were identified as being frail. Compared with men who were not frail, frail men were older, consumed less alcohol, had a higher mean BMI and were more likely to be of manual social class, report CVD and be long term ex-smokers (Table 1). Three dietary patterns were

identified using PCA; (i) a prudent dietary pattern high in poultry, fish, vegetables, legumes, pasta and rice, and eggs, (ii) a high fat/low fibre pattern and (iii) a high sugar pattern [21].

At follow-up a maximum of 945 men provided complete data on covariates (for the EDI exposure, slightly less for the HDI and dietary patterns), 181 of whom were frail. Men who were not frail at baseline but did not provide frailty data at follow-up were slightly older at baseline, more likely to be of manual social class or report CVD, and had a slightly higher energy intake than men who contributed data at follow-up, but there was no difference in smoking, alcohol or BMI (Table Appendix 1). Men with greater adherence to the EDI at baseline were less likely to be frail at follow-up (top vs bottom category OR 0.49, 95% CI 0.30, 0.80), as were men with a greater adherence to the prudent dietary pattern (top vs bottom quartiles OR 0.57, 95%CI 0.33, 0.99), whilst men with a greater adherence to the high fat/low fibre pattern were more likely to be frail (top vs bottom quartile 2.55 (95%CI 1.48, 4.37) (Table 2, model 1). No associations were seen for the HDI or high sugar pattern. Adjustment for BMI made minor differences to the findings (Model 2). Adjusting for CRP slightly attenuated the association between the high fat/low fibre pattern and frailty (Table 2, model 3) but the association remained significant.

Discussion

In this study of older community-dwelling British men, we observed that a healthier diet at baseline, as indicated by the EDI, prudent pattern or high fat/low fibre pattern was associated with a lower odds of being physically frail at follow-up, although we found no associations for the HDI or high sugar pattern. Very few studies have examined the associations of overall dietary quality or patterns (rather than single nutrients) with frailty in community dwelling

adults. Four out of five observational studies investigated the Mediterranean Diet Score (MDS), two studies in Mediterranean countries (Italy and Spain), [13,28] the others in Germany [12] and Hong Kong [14]. A higher MDS score was associated with a lower risk of frailty, cross-sectionally in Germany [12] and longitudinally over 3y in Spain [13] and 6y in Italy [28]. In Hong Kong however, the MDS was not associated with frailty, although a higher score on the Diet Quality Index–International, another *a priori* diet quality measure was associated with a lower risk of frailty [14]. In the US, a higher score on the Diet Quality Index–Revised was related to a lower risk of frailty in men [29]. The UK has been shown to have a low adherence to a Mediterranean diet [30] and we therefore used the EDI, which has similarities to the MDS but was developed specifically for older adults, [22] and higher EDI scores have been associated with lower risks of all-cause, CVD mortality and mobility limitation in this cohort previously [18,20]. *A posteriori* dietary patterns have been little explored; in Spain Leon-Munoz et al found that a "prudent" dietary pattern was associated with a lower risk of frailty but a "Westernized" pattern showed no association, [31] whilst in Hong Kong, Chan et al found none of the three patterns identified in their data, "vegetables-fruits", "snacks-drinks-milk products" and "meat-fish" were associated with frailty [15]. To the best of our knowledge this is the first study in the UK to investigate associations between diet quality or patterns and frailty.

Despite the men in our study being generally low consumers of foods in the Mediterranean diet; 90% of men scored ≤28 points on the EDI compared with 41% of adults in Kourlaba et al's study [22], we found a healthier diet as indicated by the EDI was associated with a lower risk of frailty. Dietary quality has been suggested to influence frailty by a number of mechanisms. In particular, the higher levels of antioxidants in a Mediterranean type diet may ameliorate the oxidative stress associated with frailty, and/or the lower levels of

inflammatory markers are associated with a Mediterranean diet whilst higher levels are associated with frailty. We were able to examine whether associations might be mediated via inflammation (by adjusting for CRP) but this did not seem to be the case in our study.

The lack of association between the HDI and incident frailty may be explained by the fact that specific food/food groups, as used in the EDI, are simpler to measure and less prone to measurement error compared with generating total dietary macro- and micronutrient intakes required for the HDI, which assumes standard portion sizes of foods consumed and relies on having a food composition database that is complete and current [32]

Our study sample is large and data were collected prospectively. Men who were less healthy were less likely to attend the follow-up for this study but this would likely mean our results are conservative. Our frailty outcome measure was based on self-reported measures of frailty components, as opposed to the baseline measure of frailty, which included objective measures of grip strength and walking speed. It is possible that our self-reported outcome measures underestimated the incidence of frailty. Nevertheless, we have shown that this frailty measure is robust and is just as predictive of known adverse outcomes of frailty (disability, falls, mortality) as frailty measures comprising objective components [26]. We measured diet using a previously validated FFQ which whilst less demanding than weighed intakes or diaries may be subject to increased non-response in older people. *A posteriori* dietary patterns have the advantage in being data-driven rather than based on previous assumptions, but the method does involve subjective decisions such as in grouping of dietary variables and identifying components to retain. The men in our study are almost exclusively white European and therefore findings may not be generalizable to women, who show higher frailty prevalence than men [1] or other ethnic groups.

Conclusions

In summary, we found a higher EDI score or greater adherence to a prudent dietary pattern was associated with a lower risk of frailty after three years of follow up, whilst a higher adherence to a high fat/low fibre pattern was associated with a higher risk of frailty. Thus even in older men with a relatively low consumption of foods emphasised by the EDI (and Mediterranean diet), eating more of these foods may be important for the prevention or delay of onset of frailty. Further prospective studies are required to further understand the role of nutrition in the prevention of frailty and identifying macronutrients and micronutrients associated with frailty.

References

1. Clegg A, Young J, Iliffe S, et al. Frailty in elderly people. Lancet 2013;381(9868):752-62.

2. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56(3):M146-56.

3. Hubbard RE, Lang IA, Llewellyn DJ, Rockwood K. Frailty, body mass index, and abdominal obesity in older people. J Gerontol A Biol Sci Med Sci. 2010;65(4):377-81.

4. Shamliyan T, Talley KM, Ramakrishnan R, et al. Association of frailty with survival: a systematic literature review. Ageing Res Rev 2013;12(2):719-36.

5. Kojima G. Frailty as a predictor of hospitalisation among community-dwelling older people: a systematic review and meta-analysis. J Epidemiol Community Health 2016;70(7):722-9.

6. Kojima G. Frailty as a predictor of disabilities among community-dwelling older people: a systematic review and meta-analysis. Disabil Rehabil 2017:39(19):1897-1908.

7. Gill TM, Gahbauer EA, Allore HG, et al. Transitions between frailty states among community-living older persons. Arch Intern Med 2006;166(4):418-23.

8. Puts MT, Toubasi S, Andrew MK, et al. Interventions to prevent or reduce the level of frailty in community-dwelling older adults: a scoping review of the literature and international policies. Age Ageing 2017;46(3):383-392.

9. Ramsay SE, Arianayagam DS, Whincup PH, et al. Cardiovascular risk profile and frailty in a population-based study of older British men. Heart 2015;101(8):616-22.

10. Power SE, Jeffery IB, Ross RP, et al. Food and nutrient intake of Irish community-dwelling elderly subjects: who is at nutritional risk? J Nutr Health Aging 2014;18(6):561-72.

11. Lafortune , Martin S, Kelly S, et al. Behavioural Risk Factors in Mid-Life Associated with Successful Ageing, Disability, Dementia and Frailty in Later Life: A Rapid Systematic Review. PLoS One 2016;11(2):e0144405.

12. Bollwein J, Diekmann R, Kaiser MJ, et al. Dietary quality is related to frailty in community-dwelling older adults. J Gerontol A Biol Sci Med Sci 2013;68(4):483-9.

13. Leon-Munoz LM, Guallar-Castillon P, Lopez-Garcia E, et al. Mediterranean diet and risk of frailty in community-dwelling older adults. J Am Med Dir Assoc 2014;15(12):899-903.

14. Chan R, Leung J, Woo J. Dietary Patterns and Risk of Frailty in Chinese Community-Dwelling Older People in Hong Kong: A Prospective Cohort Study. Nutrients 2015;7(8):7070-84.

15. Soysal P, Stubbs B, Lucato P, et al. Inflammation and frailty in the elderly: A systematic review and meta-analysis. Ageing Res Rev 2016;31:1-8.

16. Mendonca N, Hill TR, Granic A, et al. Micronutrient intake and food sources in the very old: analysis of the Newcastle 85+ Study. Br J Nutr 2016;116(4):751-61.

17. Mendonca N, Hill TR, Granic A, et al. Macronutrient intake and food sources in the very old: analysis of the Newcastle 85+ Study. Br J Nutr 2016;115(12):2170-80.

18. Parsons TJ , Papachristou E, Atkins JL, Papacosta O, Ash S,   Lennon LT, Whincup PH, Ramsay SE, Wannamethee SG. Healthier diet quality and dietary patterns are associated with lower risk of mobility limitation in older men. Eur J Nutr. 2018 Jul 23. doi: 10.1007/s00394-018-1786-y. [Epub ahead of print].

19. Fried LP, Ferrucci L, Darer J, Williamson JD, Anderson G. Untangling the concepts of disability, frailty, and comorbidity: Implications for improved targeting and care. J Gerontol A Biol Sci Med Sci. 2004;59:255–63.

20. Atkins JL, Whincup PH, Morris RW, et al. High diet quality is associated with a lower risk of cardiovascular disease and all-cause mortality in older men. J Nutr 2014;144(5):673-80.

21. Yarnell JW, Fehily AM, Milbank JE, et al. A short dietary questionnaire for use in an epidemiological survey: comparison with weighed dietary records. Hum Nutr Appl Nutr 1983;37(2):103-12.

22. Kourlaba G, Polychronopoulos E, Zampelas A, et al. Development of a diet index for older adults and its relation to cardiovascular disease risk factors: the Elderly Dietary Index. J Am Diet Assoc 2009;109(6):1022-30.

23. Atkins JL, Whincup PH, Morris RW, et al. Dietary patterns and the risk of CVD and all-cause mortality in older British men. Br J Nutr 2016;116(7):1246-1255.

24. Holland B, Welch AA, Unwin ID, et al. McCance andWiddowson's the composition of foods. 5 ed: Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food; 1991.

25. Wannamethee SG, Lowe GD, Whincup PH, et al. Physical activity and hemostatic and inflammatory variables in elderly men. Circulation 2002;105(15):1785-90.

26. Papachristou E, Wannamethee SG, Lennon LT et al. Ability of Self-Reported Frailty Components to Predict Incident Disability, Falls, and All-Cause Mortality: Results From a Population-Based Study of Older British Men. J Am Med Dir Assoc. 2017;18:152-157.

27. Ramsay SE, Papachristou E, Watt RG et al. Influence of Poor Oral Health on Physical Frailty: A Population-Based Cohort Study of Older British Men. J Am Geriatr Soc. 2018;66:473-479.

28. Talegawkar SA, Bandinelli S, Bandeen-Roche K, et al. A higher adherence to a Mediterranean-style diet is inversely associated with the development of frailty in community-dwelling elderly men and women. J Nutr 2012;142(12):2161-6.

29. Shikany JM, Barrett-Connor E, Ensrud KE, et al. Macronutrients, diet quality, and frailty in older men. J Gerontol A Biol Sci Med Sci 2014;69(6):695-701.

30. da Silva R, Bach-Faig A, Raido Quintana B, et al. Worldwide variation of adherence to the Mediterranean diet, in 1961-1965 and 2000-2003. Public Health Nutr 2009;12(9A):1676-84.

31. Leon-Munoz LM, Garcia-Esquinas E, Lopez-Garcia E, et al. Major dietary patterns and risk of frailty in older adults: a prospective cohort study. BMC Med 2015;13:11.

32. Willett W. Nutritional epidemiology. 2nd ed. Oxford: Oxford University Press; 1998.

Table 1. Characteristics of 1660 British men by frailty groups. Figures are mean (SD) unless stated otherwise.

Characteristic	Not Frail (n=1375)[a]	Frail (n=285)[a]	p	N
Age (y)	77.9 (4.3)	80.5 (5.4)	<0.0001	1660
Manual Social class,%	45.5	52.8	0.03	1612
CVD, %	13.8	22.1	<0.0001	1660
Smoker (current/recent), %	7.9	8.1		
Smoker (long term ex), %	52.6	61.1		
Smoker (never), %	39.4	30.9	0.02	1649
Alcohol (units per week)	6.4 (7.6)	4.9 (7.1)	0.002	1617
Energy Intake (kcal/day)	1972 (507)	1947 (536)	0.5	1542
BMI (kg/m^2)	27.0 (3.6)	27.7 (4.5)	0.004	1642
CRP (mg/l)[b]	1.2 (3.2)	1.9 (3.6)	<0.0001	1546

Frailty based on meeting at least 3 of 5 criteria: unintentional weight loss, lowest quintile for grip strength, low physical activity, exhaustion

Pearson chi-square test was used for all categorical variables

[a] maximum N in category, varies slightly with missing covariate data

[b] geometric means given due to skewed data

CVD, cardiovascular disease

BMI, body mass index

CRP, C-reactive protein

Table 2. Prospective associations between dietary quality or patterns at baseline and frailty at follow-up, odds ratios (OR) and 95% confidence intervals (CI)

	Cases	Model 1 OR	(95% CI)	Model 2 OR	(95%CI)	Model 3 OR	(95% CI)
EDI categories							
score 9-22	48	1.00		1.00		1.00	
score 23-24	45	0.90	(0.55,1.47)	0.85	(0.52, 1.4)	0.99	(0.59, 1.65)
score 25-26	49	0.66	(0.41,1.07)	0.61	(0.37, 0.98)	0.55	(0.33, 0.94)
score 27-28	39	**0.49**	**(0.30,0.80)**	0.49	(0.30, 0.82)	0.51	(0.30, 0.88)
		n=945	p=0.002	n=940	p=0.002	n=883	p=0.003
HDI categories							
score 0-1	30	1.00		1.00		1.00	
score 2	41	1.00	(0.57,1.74)	1.02	(0.58, 1.8)	0.88	(0.48, 1.62)
score 3	41	0.83	(0.48,1.45)	0.88	(0.5, 1.54)	0.94	(0.52, 1.69)
score 4-8	37	0.65	(0.37,1.15)	0.71	(0.40, 1.27)	0.73	(0.39, 1.35)
		n=801	p=0.08	n=796	p=0.171	n=748	p=0.361
Prudent dietary pattern quartiles							
1	57	1.00		1.00		1.00	
2	52	0.89	(0.56,1.40)	0.86	(0.54, 1.37)	0.87	(0.53, 1.43)
3	31	0.44	(0.26,0.74)	0.43	(0.25, 0.73)	0.48	(0.27, 0.83)
4	35	**0.57**	**(0.33,0.99)**	0.53	(0.30, 0.92)	0.47	(0.26, 0.85)
		n=924	0.007	n=919	p=0.003	n=862	p=0.003
High fat/low fibre pattern quartiles							
1	34	1.00		1.00		1.00	
2	42	1.34	(0.80,2.22)	1.35	(0.80, 2.28)	1.12	(0.65, 1.94)
3	42	1.65	(0.98,2.79)	1.62	(0.95, 2.77)	1.23	(0.70, 2.16)
4	57	**2.55**	**(1.48,4.37)**	2.54	(1.46, 4.4)	2.05	(1.15, 3.62)
		n=924	0.001	n=919	p=0.001	n=862	p=0.015
High sugar pattern quartiles							
1	44	1.00		1.00		1.00	
2	51	0.95	(0.58,1.56)	0.99	(0.60, 1.63)	1.14	(0.67, 1.95)
3	41	0.72	(0.42,1.25)	0.78	(0.45, 1.36)	0.80	(0.44, 1.45)
4	39	0.61	(0.32,1.16)	0.67	(0.35, 1.28)	0.64	(0.32, 1.3)
		n=924	p=0.09	n=919	p=0.158	n=862	p=0.123

Bold type indicates significance at the 5% level, difference from lowest category / 1st quartile.

P values given for trend

EDI, Elderly Dietary Index

HDI, Healthy Diet Indicator

Model 1: adjusted for age, social class, region of residence, smoking, alcohol consumption, cardiovascular disease, energy intake

Model 2: adjusted as for model 1 + BMI

Model 3: adjusted as for model 2 plus CRP

Physical frailty in older men: prospective associations with diet quality and patterns

SUPPLEMNTARY DATA

Appendix 1. Characteristics of 1375 British men not frail at baseline by response at follow-up. Figures are mean (SD) unless stated otherwise.

Characteristic at baseline	Responder at follow-up (frailty data provided) (n=1089)[a]	Non-responder at follow-up (frailty data not provided) (n=286)[a]	p	N
Age (y)	77.7 (4.2)	78.9 (4.6)	<0.0001	1375
Manual Social class,%	44	52	0.012	1339
CVD, %	12	21	<0.0001	1375
Smoker (current/recent), %	7.3	10.3		
Smoker (long term ex), %	52.5	53.0		
Smoker (never), %	40.2	36.7	0.2	1364
Alcohol (units per week)	6.5 (7.9)	5.7 (6.2)	0.1	1333
Energy Intake (kcal/day)	1956 (497)	2037 (539)	0.02	1288
BMI (kg/m^2)	26.9 (3.5)	27.3 (4.0)	0.1	1367
CRP (mg/l)[b]	1.19 (3.16)	1.51 (3.46)	0.002	1289

Frailty based on meeting at least 3 of 5 criteria: unintentional weight loss, lowest quintile for grip strength, low physical activity, exhaustion

Pearson chi-square test was used for all categorical variables

[a] maximum N in category, varies slightly with missing covariate data

[b] geometric means given due to skewed data

CVD, cardiovascular disease

BMI, body mass index

CRP, C-reactive protein